Interagency Ecology Program Pelagic Organism Decline
Habitat Study Group
Draft 2009 Conceptual Work Plan
Evaluation of the Effects of Fall X2 on Delta Smelt

Preliminary Study Questions

On December 15, 2008 the U.S. Fish and Wildlife Service issued a Biological Opinion (Operations Criteria and Plan—OCAP BO) on the effects of the continued operation of the Federal Central Valley Project (CVP) and State Water Project (SWP) on delta smelt and its critical habitat (FWS 2008). The general problem identified in the OCAP BO was that by reducing fall outflow to consistently low levels in all water year types (increasing fall X2 to consistently high levels), the CVP and SWP operations were significantly reducing the amount of available habitat for maturing delta smelt and that this was likely to have a negative effect on the population.

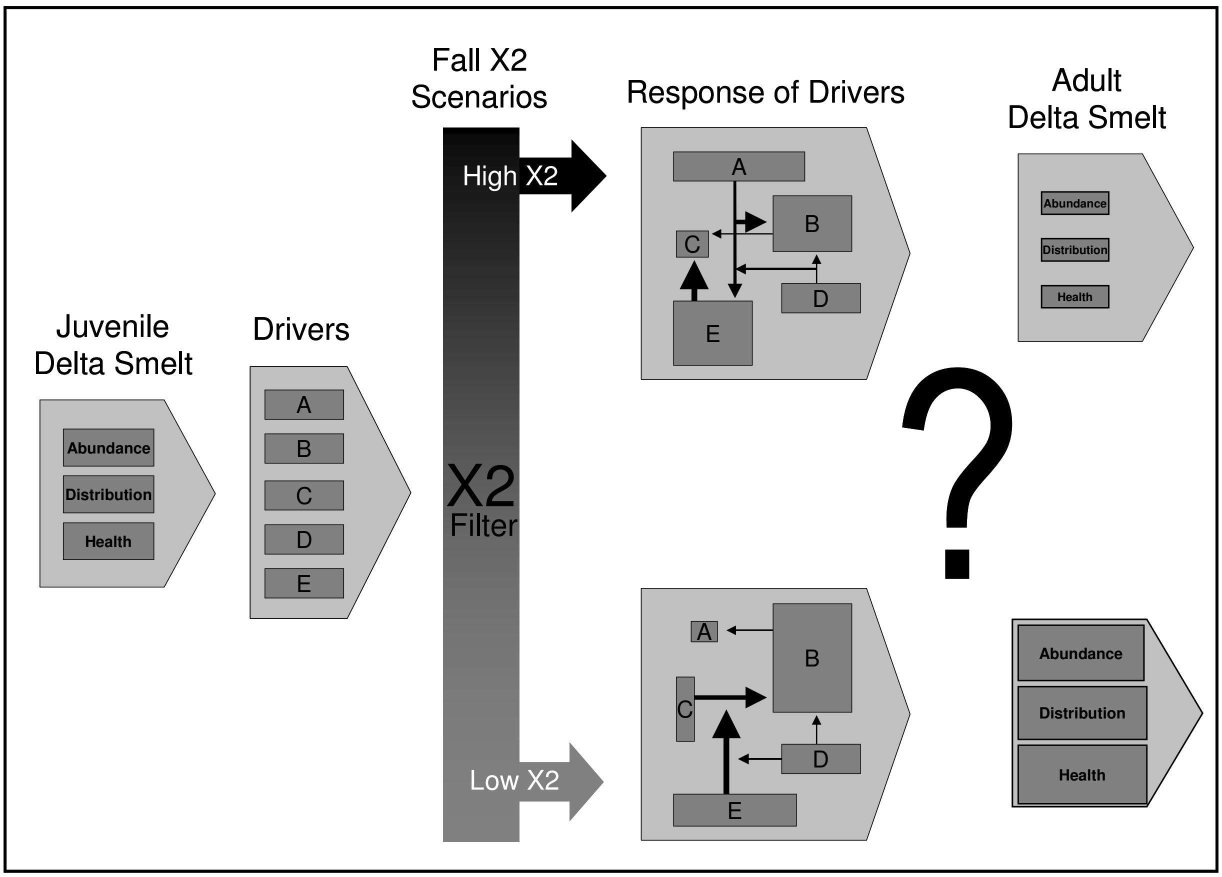
The OCAP BO provided a regulatory mechanism to address this problem in component 3 of the Reasonable and Prudent Measures (RPA) required to avoid jeopardizing the continued existence of delta smelt. The objective of RPA component 3 is to improve fall habitat for delta smelt by increasing Delta outflow during fall of wet and above normal water years, based on the scientific opinion of the Service that increased outflow will increase fall habitat quality and quantity to benefit designated critical habitat of delta smelt.

Given the uncertainty about many of the ecological mechanisms underlying delta smelt responses to changes in fall habitat, and many of the known fish-X2 relationships, the OCAP BO clearly acknowledged that there may be means other than increasing Delta outflow to avoid adverse effects to delta smelt during fall. Consequently, the RPA provides for targeted research and adaptive management of the action based on improved understanding of the scientific basis for the action and practical experience implementing the action. After 10 years or sooner, the Service will conduct a comprehensive review of: the action, any new science supporting or refuting it, and the adaptive management program, to determine their efficacy. Depending on the outcome of this review, the Service will then continue, modify, or discontinue the action. Because of the specific regulatory requirement, the primary goal of this study program is to examine the effects of fall X2 changes on delta smelt. We expect that this study program will also provide key information regarding the apparent ecological regime shift identified by the Pelagic Organism Decline (POD) investigations conducted by the Interagency Ecological Program (IEP) since 2005. The habitat study will be will be a central, distinct component of the POD investigations that will be complemented and contextualized by other POD elements.

Fall X2 and Delta Smelt Conceptual Model

We have an intentionally simple conceptual model of how X2 may affect population abundance, distribution, and health of delta smelt by its effects on various drivers, and interactions among drivers (Figure 1). Health includes fecundity, recent growth and feeding rate, and body condition, as well as the presence of diseases or parasites. The underlying hypothesis illustrated by the model is that, given a standardized starting point, population parameters of adult delta smelt may vary inversely with fall X2.

Figure 1: Delta Smelt Habitat Study Conceptual Model <DRAFT>



From the population parameters for juvenile delta smelt before fall, the model illustrates two potential pathways – high or low X2 - and resulting end points for the population parameters for adult delta smelt after fall. The conceptual model represents X2 as a filter with either a negative (smaller boxes) or positive (larger boxes) responses in delta smelt population parameters. The X2 filter modulates the effects of drivers and their interactions in various ways, as illustrated by differently sized and shaped boxes and arrows in the two X2 scenarios. Note that the model also captures the possibility that X2 may not affect some drivers (e.g., the size and shape of driver D does not vary between the two scenarios).

The drivers (illustrated as boxes labeled A-E in the conceptual model) affecting delta smelt population parameters fall into three main categories: (I) Bottom-up, which includes food web interactions; (II) Top-down, which includes predation and losses to diversions; (III) Abiotic habitat, which includes all pertinent non-biotic components of habitat; and (IV) Interactions among these factors. For each driver, our working hypotheses include (a) the driver affects some combination of delta smelt abundance, distribution, or health, and (b) the effect of the driver is modulated by some combination of X2 and other drivers (i.e., interactions among drivers).

Delta Smelt Habitat Example Study Questions:

The following are examples of hypotheses and questions about responses of delta smelt and various drivers that affect delta smelt to changes in fall outflow/X2.

Population Parameters and Individual Fitness (Abundance, Mortality, Growth, Fecundity, Health and Condition)

1. *High fall X2 results in lower abundance of delta smelt.*

   - How does delta smelt adult abundance vary with fall X2?
   - How does production of juvenile smelt vary with fall X2?

2. *High fall X2 affects life history*

   - How do fall conditions affect population structure or life history characteristics of delta smelt?

3. *High fall X2 reduces delta smelt growth rates*

   - How does delta smelt growth vary with X2 in the fall?

4. *High fall X2 results in lower fecundity of delta smelt.*

   - How does delta smelt fecundity vary with fall X2?

   - How does egg quality vary with fall X2?

5. *High fall X2 reduces condition of delta smelt.*

   - How does delta smelt condition vary with fall X2?

6. *High fall X2 reduces health of delta smelt.*

   - How does delta smelt health vary with fall X2?

Bottom-Up Drivers (Foodweb, Invasives, Community Dynamics)

1. Delta smelt are food limited.

- To what extent are individual delta smelt limited by food supply in terms of their ingestion rate, growth rate, development, or survival?

- How does subsequent fecundity of delta smelt in late winter-early spring respond to feeding conditions in the fall?

2. *Low flow results in reduced transport of Pseudodiaptomus copepods from the freshwater Delta into the LSZ.*

- What is the quantitative change in transport and in the subsidy to the copepod populations in the LSZ as flow changes?
- How is this affected by the greater distance between the LSZ and the Central Delta when flows are higher?

3. *Low flow results in reduced transport of dissolved and particulate organic materials (detritus, phytoplankton, bacteria, and microzooplankton) from the freshwater Delta into the LSZ.*

- How does the transport rate of these materials to the LSZ change at the level of flows proposed for the fall?
- What is the relative importance of transport and turnover rates of these materials in the LSZ?
- How does food quantity and quality for copepods change as flow increases in the fall?

4. *High X2 exposes foodweb organisms, including phytoplankton, microzooplankton, and copepods (esp. Pseudodiaptomus) to pumping losses, with the result being lower copepod abundance in the LSZ.*

- How does the fractional daily loss of chlorophyll and labile organic matter change with X2 and export pumping rate?
- What fraction of the *Pseudodiaptomus* population is lost to export pumping?
- How do these losses affect conditions in the LSZ?

5. *Production or abundance of Microcystis increases with high X2. Microcystis may interfere with the LSZ foodweb through various mechanisms including toxic effect, nutritional deficiency, and interference with feeding by copepods.*

- How does X2 affect the abundance, distribution, or effects of *Microcystis*?
- What are the trophic dynamics by which *Microcystis* changes the zooplankton community composition?

- What is the population-level impact of *Microcystis* on copepods such as *Pseudodiaptomus*?
- How do pelagic foodwebs change when *Microcystis* blooms?
- How do *Microcystis* bloom dynamics change with X2?

6. *A persistently high X2 results in recruitment of* <u>*Corbula*</u> *and, in turn, reduction in biomass of phytoplankton, bacteria, microzooplankton, and mesozooplankton.*

- What is the response of *Corbula* to changing salinity/variable X2? For example, how does recruitment vary with salinity?
- What conditions promote large recruitment events?
- What conditions limit recruitment or limit successful growth of *Corbula* into juveniles?

7. *Movement of X2 causes a mismatch between the location of* <u>*Corbula*</u> *populations and the LSZ, reducing consumption of phytoplankton and zooplankton by clams; conversely, a stable X2 (particularly during clam recruitment periods) allows for these locations to match over a period of time, maximizing consumption by clams.*

- Does tidal and longer-term movement of X2 result in mismatch of clam, phytoplankton, and copepod populations?
- How much difference does that mismatch make to overall consumption?
- What is the magnitude of consumption of phytoplankton, microzooplankton, and mesozooplankton?
- What is the resulting effect on calanoid copepods in the LSZ?

8. *Lower outflows result in higher concentration of ammonium, suppressing phytoplankton growth and therefore biomass accumulation.*

- How important is ammonium suppression of diatom growth in the freshwater and in the low salinity regions of the estuary, compared with the suppression of biomass by clam grazing, and suppression of growth by high turbidity?
- How do the relative magnitudes of these limits on phytoplankton change as X2 changes?

9. *Changes in the shape or size of the LSZ cause a reduction in production when X2 is high.*

- Using more refined models than that used for Figure 6, how does the size and shape of the LSZ change as X2 changes?
- How does the change in depth (or fraction of the area shallow enough for net phytoplankton production) translate to changes in phytoplankton productivity or impact of benthic grazers on all foodweb components?

10. *Overlap between Pseudodiaptomus and Limnoithona increases with a landward X2, intensifying competition for food between these apparent competitors.*

- What is the nature and magnitude of competition for food between the copepods in the upper estuary?
- How does this change with X2?

11. *Overlap between Pseudodiaptomus and Acartiella increases with a landward X2, intensifying predation by Acartiella on early stages of Pseudodiaptomus.*

- What is the predation rate of *Acartiella* on different life stages of *Pseudodiaptomus*, and is it an important source of mortality?
- How does mortality and predation rate change with X2?

12. *Recruitment of gelatinous plankton to the LSZ is higher when X2 is high; this increases predation on zooplankton which in turn causes reduction in abundance of food for delta smelt.*

- Are jellyfish important components of the plankton in terms of their consumption rates?
- Does jellyfish abundance in the LSZ vary with X2?

13. *Low flow favors nutritionally inferior phytoplankton and zooplankton species.*

- To what extent does low flow (high X2) affect the community composition and nutritional quality of phytoplankton and zooplankton in the LSZ?

Top-Down Drivers (predation and losses to water diversions)

Top-down effects are predicated on the hypothesis that consumption or removal of delta smelt by piscivores and water diversions (SWP/CVP exports, power plant diversions, local agricultural diversions) is negatively related to X2.

1. *High X2 results in increased predation by striped bass.*

- Does X2 affect the spatial overlap of delta smelt and striped bass habitats and populations?
- Does low flow increase striped bass predation rates on delta smelt?
- How does flow affect the relative prey availability for SB and predation pressure on DS?

2. *High X2 results in increased predation by largemouth bass and other predators.*

- How does fall X2 affect the spatial overlap of DS and LB habitats and populations?
- How does vulnerability to predation (any predators) depend on health and nutritional status of delta smelt?
- Does the greater amount of edge habitat to the east increase the impacts of predation by littoral species on delta smelt?
- Does high X2 increase largemouth bass predation rates on delta smelt?
- How does X2 affect the relative prey availability for largemouth bass and striped bass and the associated predation rate on delta smelt?

3. *High X2 increases losses to agricultural diversions.*

- Does high X2 shift delta smelt distribution to an area with a higher risk of agricultural entrainment?
- How do agricultural operations in the Western Delta change in response to higher X2?
- How do agricultural losses of delta smelt vary with X2?

4. *High X2 increases losses to power* plants.

- Does high X2 shift delta smelt distribution to an area with a higher risk of power plant entrainment in the Sept-Nov period?
- How do power plant losses of delta smelt vary with X2?
- Does power plant entrainment present a substantial risk of mortality?

5. *High X2 increases losses to SWP and CVP export facilities*.

- How does the probability of fish entrainment during winter upstream migration vary with fall X2?

Abiotic Habitat Drivers (Habitat Quantity, Contaminants)

1. *The amount of abiotic habitat for delta smelt varies with X2*.

   - Does fall turbidity vary with fall X2?
   - How does X2 affect habitat volume/area based on salinity and water clarity?
   - How does X2 affect the habitat of delta smelt predators such as striped bass and largemouth bass?
   - Does X2 affect the abundance and distribution of submerged aquatic vegetation (SAV) such as *Egeria*?
   - Does SAV proliferation affect delta smelt spawning habitat?

2. *High fall X2 exacerbates contaminant effects*.

   - How does fall X2 affect the distribution, concentration, and effects of ammonia and ammonium?
   - How does fall X2 affect the distribution, concentration, and effects of other contaminants?
   - How does fall X2 affect the frequency of occurrence and distribution of acute and chronic toxicity of ambient water to delta smelt and their food organisms?

Interactions Among Drivers

Dividing drivers and studies into categories is important for constructing a feasible work plan. However, ecosystems, especially estuaries, are complicated. In analyzing the importance of fall X2 variability and the effects of RPA 3 we must look for evidence of sporadic, non-linear, or interactive effects of flows in the fall with other drivers and in other seasons. Most of the hypotheses and questions about these types of interactions follow from the hypotheses and questions about the effects of individual drivers, and in several cases the questions included under the individual drivers above already address various interactions.

1. *Conditions in the spring affect flow effects on delta smelt in the fall.*

- How does distribution of delta smelt in the spring and summer affect their distribution and growth in the fall?
- How do delta smelt "find" suitable fall habitat?
- How do pesticide exposure and toxicity to delta smelt in the fall vary with flows? How do pesticide exposure and toxicity in the spring affect the delta smelt population in the fall? What is the fate of contaminants mobilized in wet springs under different fall flow conditions?
- Do summer *Microcystis* blooms affect delta smelt distribution in the fall? How do flows affect this interaction?
- How do agricultural use patterns in the Delta or energy demands on power plants in Suisun Bay change with springtime conditions, and does this amplify the impacts on delta smelt by higher X2 in the following fall?

2. *Turbidity affects feeding and predation risk and modulates bottom-up and top-down effects associated with fall flows.*

- Is predation rate on delta smelt higher when water is clear than when it is turbid?
- Is feeding rate of delta smelt a function of turbidity?
- Does the latter relationship depend on the presence of predators?